A DISSERTATION ON

STUDY OF ANATOMIC VARIATIONS IN MIDDLE CEREBRAL ARTERY

In partial fulfillment of the

regulations for the award of the degree of

MASTER OF CHIRURGIE

BRANCH – II – NEURO SURGERY

3 Years

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CHENNAI – 600 032

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AUGUST - 2010

DECLARATION

I solemnly declare that this dissertation "***A DISSERTATION ON STUDY OF ANATOMIC VARIATIONS IN MIDDLE CEREBRAL ARTERY*"** was prepared by me under the guidance and supervision of Professor & HOD Department of Neurosurgery, Madurai Medical College and Government Rajaji Hospital, Madurai between **2007 and 2010.**

This is submitted to **The Tamil Nadu Dr. M.G.R. Medical University, Chennai,** in partial fulfillment of the requirement for the award of **MASTER OF CHIRURGIE, NEUROSURGERY,** degree Examination to be held in **AUGUST 2010.**

Place: Madurai.

Date :

Dr. R.JEYAKUMAR

CERTIFICATE

This is to certify that this dissertation entitled “***A DISSERTATION ON*** **STUDY OF ANATOMIC VARIATIONS IN MIDDLE CEREBRAL ARTERY”** submitted by **Dr.R.JEYAKUMAR** Post Graduate, Department of Neurosurgery, Madurai Medical College to The Tamil Nadu Dr.M.G.R.Medical University, Chennai, in partial fulfilment of the requirement in the award of degree of **MASTER OF CHIRURGIE IN NEURO SURGERY, Branch – II,** for the August 2010 examination is a bonafide research work carried out by him under our direct supervision and guidance during the year 2007-2010.

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CONTENTS

ABBREVIATIONS

M1	-	Middle cerebral artery first segment
M1SL	-	First segment of MCA Length
EBR	-	Early branches
AcomA	-	Anterior communicating artery
MCA	-	Middle cerebral artery
ACA	-	Anterior cerebral artery
ICA	-	Internal carotid artery
PP	-	Proximal perforators
DP	-	Distal perforators
LCA	-	Largest cortical angular artery
LCTO	-	Largest cortical temporo occiptal artery

INTRODUCTION

The field of microneurosurgery has gone leaps and bounds over the years which helps in better understanding of the normal anatomy and its intricate variations in the vascular and other minute structures in brain. Cadaveric micro dissection is of immense help which forms the basis of our understanding of the intricate anatomy of the structures of the brain.

Vascular anatomy of the brain is fascinatingly complex of all the variations in the brain but yet they are so conspicuous by their distinct anatomy and its unique features.

The evolution of microneurosurgery and the awareness of the arrangement of tiny perforating features vessels at the base of the brain has markedly and significantly improved the outcome and quality of life of the patients subjected to surgery related to the vascular structures of the brain.

Middle cerebral artery is the largest and most complex arterial system of the brain. Thorough knowledge of the microvascular anatomy and the myriads of variations is very essential for the operating surgeon to choose the ideal technique in order to avoid any catastrophe during and after surgery and to give the best possible functional outcome for the patients.

Various studies have been conducted in different sets of population by various authors on middle cerebral artery in an elaborate manner which includes a few studies on Indian population as well. With these various studies as guidelines an attempt has been made in this study to enhance our perception of the variations in the microvascular anatomy of middle cerebral artery in our population.

AIM OF THE STUDY

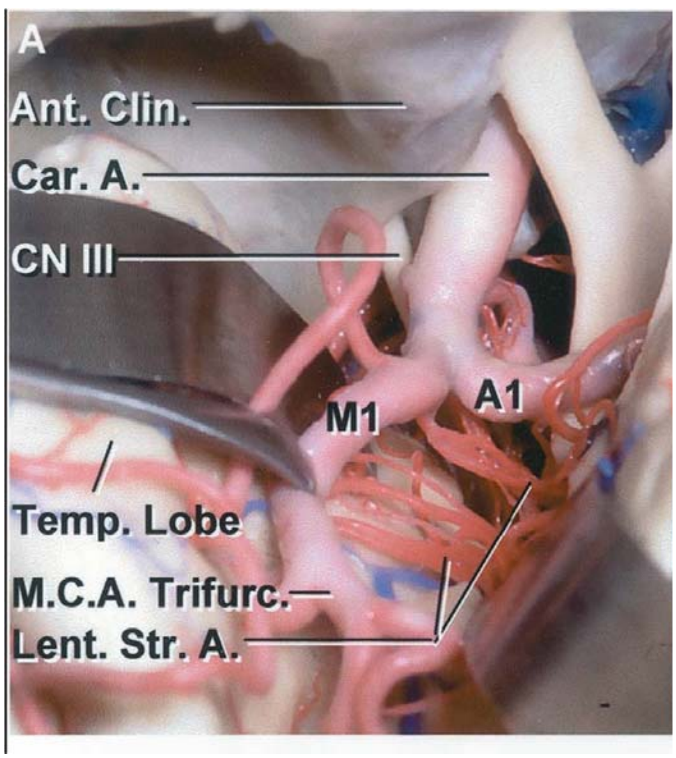
To study the variations in the microsurgical anatomy of the middle cerebral artery in our population and to compare the variables with the studies on western population and to discuss its importance with anatomic and surgical considerations.

REVIEW OF LITERATURE

MICROSURGICAL ANATOMY OF MIDDLE CEREBRAL ARTERY[1]

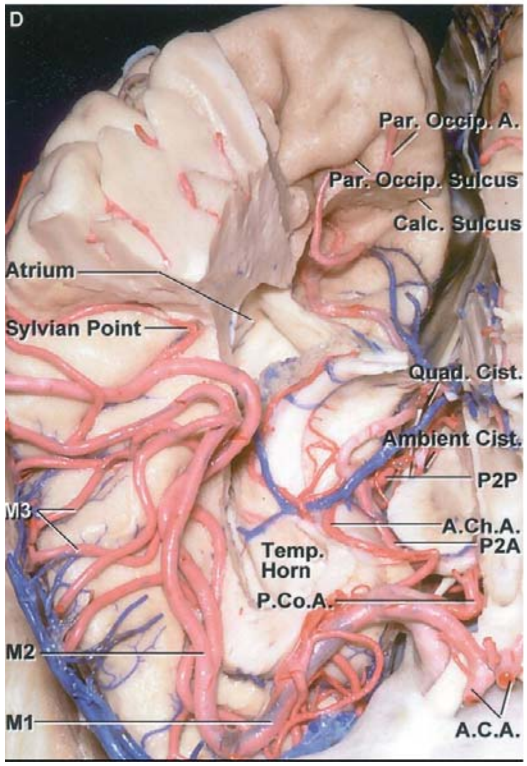
The middle cerebral artery is the largest and most complex of the cerebral arteries. Some of its branches are exposed in most operations in the supratentorial area, whether the approach is to the cerebral convexity parasaggital region, or along the cranial base. In the past surgical interest in the middle cerebral artery has been directed at avoiding damage to its branches during operations within its territory, but microoperative techniques have now made reconstruction of and bypass to the middle cerebral artery an important method of preserving and restoring blood flow to the cerebrum.

The middle cerebral artery arises as the larger of the two terminal branches of the internal carotid artery. The diameter of MCA at its origin ranges from 2.4-4.6mm roughly twice that of ACA. Its origin is at the medial end of sylian fissure, lateral to the optic chiasm, below the anterior perforated substance, and posterior to the division of the olfactory tract. From its origin it courses laterally below the anterior perforated substance, and parallel, but roughly 1cm posterior to the sphenoid ridge. As it passes below the anterior perforated substance, it gives rise to a series of perforating branches referred to as lenticulostriate arteries. It divides within the sylian fissure and turns sharply posterosuperiorly at a curve, the genu to reach the surface of the insula. At the pheriphery of the insule the branches pass to the medial surface of the opercula of the frontal, temporal, and parietal lobes. Its branches pass around the opercula to reach the cortical surface and supply most of the lateral surface and some of the basal surface of the cerebral hemisphere.



SEGMENTS

The middle cerebral artery is divided in to four segments M1 (Sphenoidal), M2 (insular), M3 (opercular) and M4 (Cortical). The M1 begins at the origin of MCA and extends laterally within the depths of sylvian fissure. It courses laterally roughly parallel to an approximately 1cm posterior to the sphenoid ridge in the sphenoidal compartment of the sylvian fissure. This segment terminates at the site of a 90^0 degree turn, the genu located at the junction of the sphenoidal and operculoinsular compartments of the sylvian fissure, the M1 is subdivided in to a prebifurcation and postbifurcation part. The prebifurcation segment is composed of a single main trunk that extends from the origin to the bifurcation. The postbifurcation and trunks of the M1 segment run in a nearly parallel course. This bifurcation occurs proximal to the genu in nearly 90% of the hemispheres(2). The small cortical branches arising from the main trunk proximal to the bifurcation are referred to as early branches.



The M2 segment includes the trunks that lie on and supply insula. This segment begins at the genu where the MCA, trunks passess over the limen insulae and terminates at the circular sulcus of the insula. The greatest branching of the MCA occurs distal to the genu as these trunks cross the anterior part of the insula. The branches passing to the anterior cortical areas have a shorter path across the insula than those reaching the posterior cortical areas. The branches to the anterior frontal and anterior temporal areas cross only the anterior part of the insula, but the branches supplying the posterior cortical areas course in a nearly parallel but divergent path across the length of the insula. The frontal branches cross only the short gyri before leaving the insular surface, whereas the branches supplying the posterior parietal or angular regions pass across the short gyri, the central sulcus, and the long gyri of the insula before leaving the insular surface.

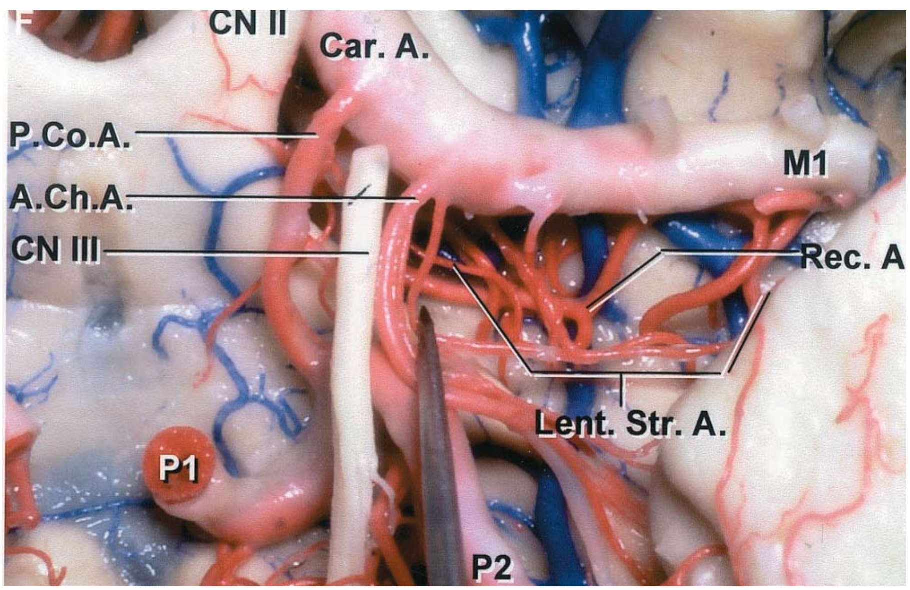
The M3 segment begins at the circular sulcus of the insula and ends at the surface of the sylvian fissure. The branches forming the M3 segment closely adhere to and course over the surface of the frontoparietal and temporal opercula to reach the superficial part of the sylvian fissure. The branches directed to the brain above the sylvian fissure and undergo two180 degree turns. The first turn is located at the circular sulcus, where the vessels coursing upward over the insular surface turn 180-degrees and pass downwards over the medial surface of the frontoparietal operculum. The second 180-degree turn is located at the external surface of the sylvian fissure, where the branches complete their passage around the inferior margin of the frontoparietal operculum and turn in a superior direction on the lateral surface of the frontal and parietal lobes.

The arteries supplying the cortical areas below the sylvian fissure pursue a less tortuous course. These branches, on reaching the circular sulcus, run along its inferior circumference before turning upward and laterally on the medial surface of the temporal operculum thus producing a less acute change in course at the inferior margin of the circular sulcus. On reaching the external surface of the sylian fissure, these branches are directed downward and backward on the surface of the temporal lobe.

The M4 is composed of the branches to the lateral convexity. They begin at the surface of the sylvian fissure and extend over the cortical surface of the cerebral hemisphere. The more anterior branches turn sharply upward or downward after leaving the sylvian fissure. The intermediate branches follow a gradual posterior incline away from the fissure, and the posterior branches pass backward in nearly the same direction as the long axis of the fissure.

PERFORATING BRANCHES

The perforating branches of the middle cerebral artery enter the anterior perforated substance and are called the lenticulostriate arteries. There is an average of 10 lentrculostriate arteries per hemisphere(3). Of the total number of lenticulostriate branches approximately 80% arise from the prebifurcation part of M1. Most of the remainder arise from the postbifuration part of the M1, but a few arise from the proximal part of M2 near the genu. The earlier the bifurcation the greater the number of postbifurcation branches.



The lenticulostriate arteries are divided into medial, intermediate, and lateral groups, each of which has a unique origin, composition, morphology and characteristic distribution in the anterior perforated substance. The medial group is the least constant of the three groups and is present in only half of the hemisphere[(3)]. When present it consists of one to five branches that arise on the medial prebifurcation part of the M1 segments near the carotid bifurcation or an early branch and pursue a relatively direct course to enter the anterior perforated substance just lateral to c4 branch of ICA.

The intermediate lenticulostriate arteries arise almost exclusively on the M1 or its early branches. Most arise from the posterior, posterosuperior, or superior aspect of the MCA. They from a complex array of branches before entering the anterior perforated substance between the medial and lateral lenticulostriate arteries. The most distinctive feature of the intermediate group is that if possesses at least one major artery which arborizes to as many as 30 branches to the anterior perforated substance.

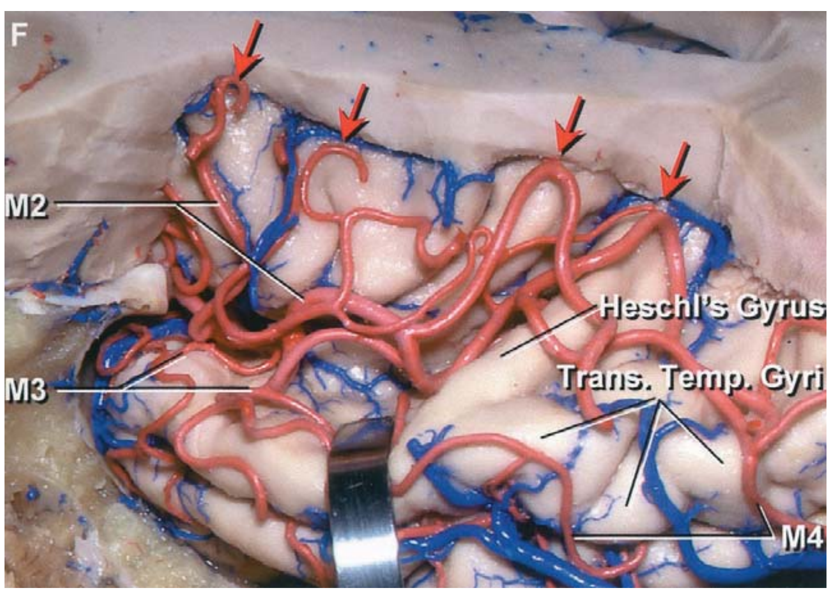
The lateral lenticulostriate arteries originate predominantly on the lateral part of M1, pursue an S-Shaped course, and enter the posterolateral part of the anterior perforated substance after arborizing in to 20 branches. They may also arise from early branches of M1 the branches with a more medial origin arise at a less acute angle to the parent vessel and pursue a more direct posterior, superior and medial route to the anterior perforated substance.

The lateral and intermediate group of lenticulostriate arteries pass through the putamen and arch medially and posteriorly to supply almost the entire anterior – to posterior length of the upper part of the internal capsule and the body and head of the caudate nucleus. The medial lenticulostriate arteries irrigate the area medial to and below that supplied by the lateral and intermediate lenticulostriate arteries; this area includes the lateral part of the globus pallidus, the superior part of the anterior limb of the internal capsule, and the anterosuperior part of the head of the caudate nucleus.

CORTICAL DISTRIBUTION

The cortical territory supplied by the middle cerebral artery includes the insular and opercular surfaces the lateral part of the orbital surface of the frontal lobe, the temporal pole, and the lateral part of the inferior surface of the temporal lobe. It also extends around the lower margin of the cerebral hemisphere onto the inferior surfaces of the frontal and temporal lobes.

The cortical areas supplied by the MCA is divided in to 12 areas



1. **Orbitofrontal area:** The orbital portion of the middle and inferior frontal gyri and the inferior part of the pars orbitalis.

2. **Prefrontal area :** the superior part of the pars orbitalis, the pars triangularis, the anterior part of the pars opercularis, and most of the middle frontal gyrus.

3. **Precentral area :** The posterior part of the pars opercularis and the middle frontal gyrus, and the inferior and middle portions of the precentral gyrus.

4. **Central area :** The superior part of the precentral gyrus and the inferior half of the post central gyrus.

5. **Anterior parietal area :** The superior part of the postcentral gyrus, and frequently, the upper part of the central sulcus, the anterior part of the inferior parietal lobule, and the anteroinferior part of the superior parietal lobule.

6. **Posterior parietal area :** The posterior part of the superior and inferior parietal lobules, including the supramarginal gyrus.

7. **Angular area :** The posterior part of the superior temporal gyrus, variable portions of the supramarginal and angular gyri, and the superior parts of the lateral occipital gyri.

8. **Temporo – occipital area :** The posterior half of the superior temporal gyrus, the posterior extreme of the middle and inferior temporal gyri, and the inferior parts of the lateral occipital gyri.

9. **Posterior temporal area :** The middle and posterior part of the superior temporal gyrus, the posterior third of the middle temporal gyrus, and the posterior extreme of the inferior temporal gyrus.

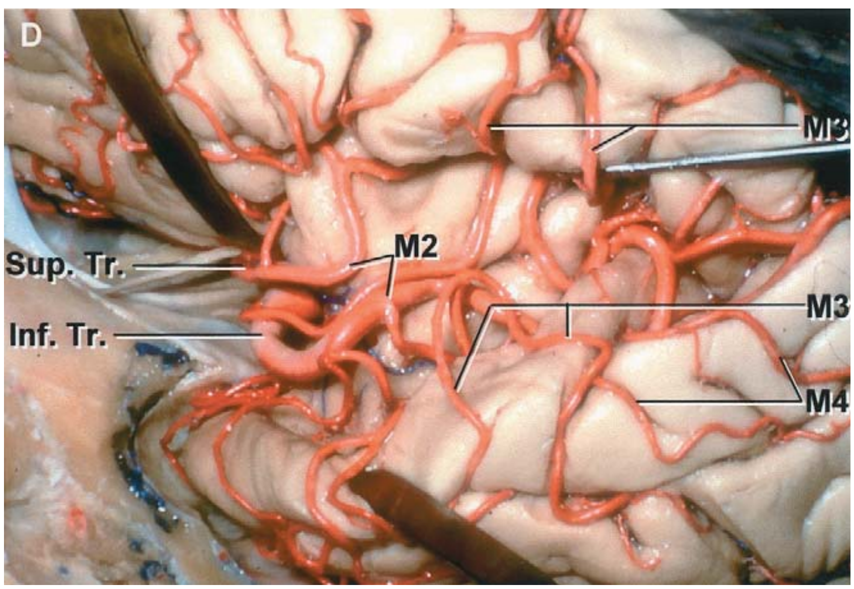
10. **Middle temporal area :** The superior temporal gyrus near the level of the pars triangularis and pars opercularis, the middle part of the middle temporal gyrus, and the middle and posterior part of the inferior temporal gyrus.

11. **Anterior temporal area:** The anterior part of the superior, middle, and inferior temporal gyri.

12. **Temporopolar area:** The anterior pole of the superior, middle and inferior temporal gyri.

Branching Pattern

The main trunk of the middle cerebral artery divides in one of three ways. Bifurcation in to superior and inferior trunks; trifurcation into superior, middle, and inferior trunks; or division into multiple trunks. The distal division of the middle cerebral artery also generally occurs in a series of bifurcation. The small arteries that arise proximal to the bifurcation or trifurcation and are distributed to the frontal or temporal pole are referred to as early branches.



The MCAs that bifurcate are divided into three groups, designated equal bifurcation, superior trunk dominant, and inferior trunk dominant, based on the diameter and the size of the cortical area of supply the equal bifurcation yields two trunks with nearly equal diameters and the size of the cortical area. The inferior trunk supplies the temporal, temporo-occipital, and angular areas, and the superior trunk supplies the frontal and parietal regions. The superior trunk usually supplies the orbitofrontal to the posterior parietal areas and the inferior trunk usually supplies the angular to the temporopolar areas. The inferior trunk dominant type of bifurcation yields a larger inferior trunk that supplies the temporal and parietal lobes and a smaller superior trunk that supplies all part of the frontal lobe. The superior trunk dominant type of bifurcation yields a larger superior trunk that supplies the frontal and parietal regions and a smaller inferior trunk that supplies only the temporal lobe.

STEM ARTERIES

The stem arteries arise from the trunks and give rise to the individual cortical branches. They arise from the main trunk and the two or more trunks formed by a bifurcation, trifurcation, or division in to multiple trunks. There is considerable variation in the number and size of the area supplied by the stem arteries. The most common pattern is made up of 8 stem arteries per hemisphere[2].

The individual stem arteries give rise to one to five cortical arteries. The most common pattern is for one of the 12 cortical areas to be supplied by a stem artery supplying one or two adjacent areas. The cortical areas most commonly receiving a stem artery serving only that area are the temporo-occipital, angular, and central areas. Stem arteries supplying four or five of the cortical areas are most commonly directed to the area below the sylvian fissure. The most common pattern, two-stem pattern had one stem giving rise to the orbitofrontal, prefrontal, and precentral arteries, and the other stem giving rise to the central artery.

CORTICAL ARTERIES:

The cortical arteries arise from the stem arteries and supply the individual cortical areas. The smallest cortical arteries arise at the anterior end of the sylvian fissure and the largest arteries arise at the posterior limbs of the fissure. The cortical branches to the frontal, anterior temporal, and anterior parietal areas are smaller than those supplying the posterior parietal, posterior temporal, temporo occipital, and angular areas. The smallest arteries supply the orbitofrontal and temporopolar areas, and the largest ones supply the temporo-occipital and the angular area.

There is an inverse relationship between the size and the number of the arteries supplying a cortical area. The temporo-occipital area has the smallest number of arteries, but they are the largest in size, and the prefrontal areas has the largest number of arteries, but they are smaller. The temporopolar, temporo –occipital, angular and anterior, middle, and posterior temporal arteries usually arise from the inferior trunk; the orbitofrontal, prefrontal, and central arteries usually arise from the superior trunk. The anterior and posterior parietal arteries have an origin evenly divided between the two trunks and usually arise form the dominant trunk.

EARLY BRANCHES

The cortical arteries arising from the main trunk proximal to the bifurcation or trifurcation are called early branches. The early branches are distributed to the frontal or temporal lobes. Nearly half of MCAs send early branches to the temporal lobe, but less than 10% give early branches to the frontal lobe(2). The temporal branches usually supply the temporopolar and anterior temporal areas. The frontal branches terminate in the orbitofrontal and prefrontal areas. A few MCAs will give rise to early branches to both the frontal and temporal lobes. There is most commonly only one early branch, but a few hemispheres will give rise to two early branches.

ANOMALIES

Anomalies of the middle cerebral artery consisting of either a duplicate or an accessory middle cerebral artery, are infrequent and occur less often than anomalies of the other intracranial arteries. A duplicated MCA is a second artery that arises from the internal carotid artery and an accessory MCA is one that arise from the anterior cerebral artery. Both the duplicate and accessory MCAs send branches to the cortical areas supplied by the MCA. The accessory MCA usually arise from the ACA near the origin of the ACOMA. The accessory MCA is differentiated from a recurrent artery of Heubner by the fact that the recurrent artery, although arising from the same part of the ACA as an accessory MCA, enters the anterior perforated substance, but the accessory MCA, although sending branches to the anterior perforated substance, also courses lateral to this area and sends branches to the cortical areas normally supplied by the middle cerebral artery.

The advent of microneurosurgical techniques and its nuances in the field of cerebrovascular surgery has renewed interest in many surgeons and anatomists like Chater et al (1976), Grand et al (1980), Gibo et al (1981) Umansky et al (1984) and to do further research on the microvascular anatomy of the cerebral vasculature.

A.L. Rhoton (2002)[1] has stated that MCA has an outer diameter of 3.5mm on an average. The incidence of early branches per hemisphere is 4-6 branches. The size of the vessel determines the area of the cortex supplied. The insular cortical incisions can be made safely only if the M2 branches over the insular cortex is carefully mobilized and one safe corridor for the insular cortical incisions in the anteroinferior part of the limiting sulcus which is devoid of large perforators.

A.L.Rhoton has also stated that the number of inferomedial perforators varies from 1-21 per hemisphere.

Yasargil M.G. (1984)[4] states that in 70% of cases studied middle cerebral artery was the larger of the branch from ICA. The inferomedial perforators of the M1 segment of the middle cerebral artery varied from 2-15 in number. The mean length of the M1 segment was 14-16mm.

Thirty percent of the time there was three arterial branches along the superior lateral aspect M1 segment and all the three branches appeared to be of same diameter and equidistant from one another. When this occurs the first branch is the uncal artery and its distribution ahs been described by Waddington[5].

Occasionally during surgical dissection both the polar temporal and anterior temporal arteries may be hypoplastic or absent and their cortical areas supplied by a single large middle temporal branch that arises from the inferior trunk of M2 bifurcation.

It is very important to be aware of these different patterns along the superolateral wall of M1 segment, both at angiography and at the time of surgery since the different anatomical patterns can lead to confusion of the position of the true middle cerebral artery bifurcation.

Three patterns of origin of the striate arteries from the M1 segment have been observed by Yasargil in his studies most frequently occurring in 40 percent of the time, the striate arteries arose from one single large artery, a stem artery that then divided after 2-10mm in to many branches.

Two other pattern of striate origin were seen in 30 percent each of the series. These pattern consisted either two large parallel arteries that immediately divided to give numerous branches of the striate group or numerous small twigs (10-15) of striate arteries that arose from the whole inferior medial M1 segment.

Yasargil M.G. in his studies has demonstrated fenestrated M1 segment as a rare anomaly encountered which was radio graphically identified by Ito et al (1977)[6].

Lang et al[7] found that the striate branches often arose from several areas. Proximal M1 branches were seen in 71 percent, mid portion branches in 86 percent, distal M1 branches in 44 percent, proximal M2 branches in conjunction with M1 branches in 41 percent and proximal M2 branches only in 14 percent.

He also states that in 20 percent of cases of trifurcations, tetrafurcation or even pentafurcation is present.

Complete comprehension of the intricate vascularisation patterns associated with the insula, as well as proficiency in insular anatomy, are prerequisites to accomplishing appropriate surgical planning and ultimately, to completing successful exploration and removal of pathological lesions in the this region.

The origin of each artery to insula could be traced to MCA, predominantly the M2 segment with a few arteries from M3 segment. The insular arteries primarily supply the insular cortex, extreme capsule, and occasionally, the claustrum and external capsula, but not the putamen, globus pallidus, or internal capsule, which are vascularised by the lateral lenticulostriate arteries[(8)].

Umansky et al[(9)] has stated that the mean length of M1 segment was 15.7mm and among all the perforators of the MCA the M1 segment contributed to 79% of the perforators and 15.3% of the perforators were from the secondary trunks and 5.7% of the perforators were from early cortical branches. He also states that the mean outer diameter of MCA is 3.4mm.

Gibo et al (1981)[2] states that in case of the bifurcating MCAs. The superior trunk was dominant in 28% and the inferior trunk was dominant in 32% of cases. 18% of cases had equal dominance. A.L.Rhoton has cited similar incidence in his article. He also states that MCA trifurcated in 78%, trifurcated in 12% and to multiple trunks in 10%.

S. Balaji Pai[10] states that the MCA at the origin has an outer diameter varying from 2.5 mm 4.6mm with a mean of 3.35mm which Yasargil M.G states that it varied from 2.4-4.6mm.

S.Balaji Pai states that the average length of the M1 Segment is 20mm and the number of inferomedial perforators varied from 3-11in number per hemisphere. The average number of stem arteries from the superior trunk was 4.5 and the average number of stem arteries from the inferior trunk is 4 arteries.

In1962 Cromptom[11] described the accessory MCA which included the duplication of MCA and the anomalous vessel originating from the A1 portion of ACA.

In 1973 Teal[12] et al proposed using the term MCA duplication to characterize the two vessels originating from the distal end of internal carotid artery and the term accessory MCA to describe the anomalous vessel originating from the ACA.

Anomalous ramifications of the MCA is important for the surgical treatment of MCA aneurysms and for understanding of the collateral blood supply in cerebral ischemia.

Masaki Komiyama[13] et al states that a consistent cortical supply by the duplicated MCA and the accessory MCA to the anterior temporal lobe, and anterior frontal lobe, respectively and its similarity to the cortical supply by the early branches of the MCA suggest the development of duplicated and / or accessory MCA is an anomalous early ramifications of the early branches of the MCA.

Chater[14] et al has stated in his analysis of the cortical zones centered over the convexity of the frontal lobe, tip of the temporal lobe, and the region of angular gyrus and were selected to be readily accessible through a small craniectomy. An external diameter of 1mm was postulated to be the minimum required for long term anastomosis patency.

Chater et al found a cortical artery with a diameter of more than 1.4mm in the angular zone in 100% hemispheres. The arteries over the tip of the temporal lobe and the frontal lobe were considerably smaller. In the temporal zone an artery with a diameter of more than 1.0mm was present in 70% of hemispheres and in the frontal zone an arterial diameter of more than 1.0mm was present only in 52%.

These authors also noted that the vessels in the region of the angular gyrus had the advantages of being located so as to be accessible for anastomosis not only with the superficial temporal artery but also with the occipital artery. They recommended that the craniectomy for exposing the cortical branches of MCA be 4cm in diameter and that it be centered 6cm above the external auditory canal.

Middle cerebral artery aneurysms form about 18.4% of all cerebral aneurysms and a though knowledge of the microanatomy of the MCA is essential to tackle these surgically(15).

MATERIALS AND METHODS

15 fresh adult cadavers of both sexes were studied in the autopsy room in Madurai Medical College, Madurai between June 2008 to January 2009.

26 gauge needle, microscissors, 11 blade knife, bayonet forceps, fine toothed forceps, poster colour, cotton, artery forceps were used for the dissection of the sylvian fissure.

4x magnification using Heine magnifying loupe was used for the dissection of the brain throughout the study.

8 megapixes canon Ixus digital camera was used for taking the photographs.

Tabulation chart was used for entering the data and for further interpretation.

PROCEDURE

During postmortem examination of the cadavers after the skull vault was removed taking special care not to injure the dura. The dura was opened from the frontal base in a transverse direction and after cutting the falx the frontal lobes were retracted slowly and the optic nerves were exposed and carefully cut along with the ICA Internal carotid artery at their entrance into cranial cavity. Both the cerebral hemispheres were lifted carefully after dividing the cranial nerves one by one.

At the level of the tentorial hiatus the brain stem along with the basilar artery was cut and the entire cerebral hemispheres delivered, after dividing the posterior attachment of falx. The specimen was soaked for 10-15 minutes in 10% formaldehyde solution.

Further dissections were carried out using magnifying loupe with 4x magnification. The sylvian fissure was opened with 26 gauge needle below the sylvian vein. And the dissection was extended with bayonet forceps.

The bifurcation of ICA is traced and then MCA was traced with its branches coursing over the insula, the operculur and cortical branches were further dissected. The origin of the ICA is ligated with a silk and red poster colour solution was injected to make the vessels and perforators prominent and for ease of dissection.

The M1 segment of MCA was carefully dissected and the early branches from the superior aspect, and the perforators from the inferior aspect were exposed.

The distribution of perforators along the middle cerebral artery and their numbers were noted.

The number and branching pattern of early branches were noted.

The branching pattern of MCA into different trunks were taken note of.

The division of the trunks in to stem arteries and their further course over the insular region, opercular region and cortical region were noted by further dissection.

The distribution of the cortical branches were taken note of.

The entire architecture of the MCA and its branches were photographed.

OBSERVATION

The following observations were made

1) Length of the middle cerebral artery (M1 segment)
2) Early branches from the middle cerebral artery
3) Perforators from
    a. M1 segment
        i. Proximal
        ii. Distal
    b. M2 segment
4) Branching pattern of MCA into
    a. Bifurcation
    b. Trifurcation
    c. Multiple branches

RESULTS AND ANALYSIS

The recorded data was analyzed with descriptive statistics and student T-test.

M1 segment length (M1SL)

The average length of M1 segment was

Longest M1 was 24mm

Shortest M1 was 12mm

Table 1

M1 segment length

	N	Minimum	Maximum	Mean	SD
M1SL	30	12mm	24mm	16.37mm	2.974

The average length of M1 in bifurcating cases : 15.32mm

The average length of M1 in trifurcating cases : 19.25mm

Table 2

M1 length in variously dividing MCA

Divisions	N	Minimum	Maximum	Mean	SD
Bifurcation	22	12	18	15.32	2.033
Trifurcation	8	14	24	19.25	3.327
Total	**30**				

The differences in M1 segment length in variously dividing MCA was found to be statistically significant using the student T-test.

Early Branches

The arteries supplying the cortical areas which take their origin directly from M1 segment of middle cerebral artery are called early branches.

It varied from one to three in each hemisphere.

33.33% had 1 early branch

46.6% had 2 early branches

20.0% had 3 early branches

Table 3

Early branches

No	Frequency	Percentage
1	10	33.33%
2	14	46.6%
3	6	20.00%

In this study where there was more than 2 early branches, one of the vessel supplied the frontal lobe by replacing the orbitofrontal artery.

Accessory MCA

Accessory MCA are arteries arising from ICA, ACA, or AcomA which traverse through the sylvian fissure to supply the cortical areas.

In this study there was no accessory MCA.

Perforating arteries

Perforators are small twigs of blood vessels that arise from major arteries such as ICA, ACA, AcomA, MCA.

The majority of perforators of the middle cerebral artery were from the inferomedial surface and they divide in a candelabra pattern before entering the anterior perforated substance.

Table 4

Perforators

	N	Minimum	Maximum	Mean	SD
M1PP	30	4	13	7.07	1.88
M1DP	30	0	6	2.8	1.24

- Average number of perforators from proximal half of MCA is 7.07.
- Average number of perforators from distal half of MCA is 2.8

- The middle cerebral artery was divided into 2 groups as short MCA and long MCA taking in to consideration 16mm as the arbitrary cut off point.

Short MCA

Proximal perforators contribute to 6.27

Distal perforators contribute to 2.91

Long MCA

Proximal perforators contribute to 7.53

Distal perforators contribute to 2.74

Table 5

MCA length vs perforators

MCA		**Proximal perf**	**Distal perf**
Short MCA	N	11	11
	Min	5	1
	Max	9	5
	Mean	6.27	2.91
	Std Deviation	1.35	1.14
Long MCA	N	19	19
	Min	4	0
	Max	13	6
	Mean	7.53	2.74
	Std deviation	2.00	1.33

There was no significant difference in the distribution of perforators in both long and short MCAs.

M2 segment of the middle cerebral artery also contributed to a few perforators.

No significant contribution of perforators from the frontal and temporal cortical branches as it is reported in other studies.

Division of MCA

MCA – bifurcated in to superior and inferior trunk in 22 cases (73.3%).

On the right side 12 trifurcations were noted and on the left side 10 trifurcations were noted.

MCA – trifurcated in to superior, middle and inferior trunks in 8 cases (26.6%).

On the right side 5 trifurcated and on the left side 3 trifurcated.

There were no multiple divisions of MCA in this study.

Table 6

Division of MCA

	Frequency	**Percentage**
Bifurcation	22	73.3%
Trifurcation	8	26.6%
Multiple	0	0
Total	**30**	**99.9**

With regard to the pattern of division between two sides there was symmetry in most cases.

Table 7

Side vs division cross tabulation

Side	**Divisions**			**Total**
	Bifurcation	**Trifurcation**	**Multiple**	
Right	12	5	0	17
Left	10	3	0	13
Total	**22**	**8**	**0**	**30**

Only in 2 cases the middle cerebral artery bifurcated on the right side and trifurcated on the left side.

There were no cases where in the MCA divided in to multiple branches in this sample.

Table 8

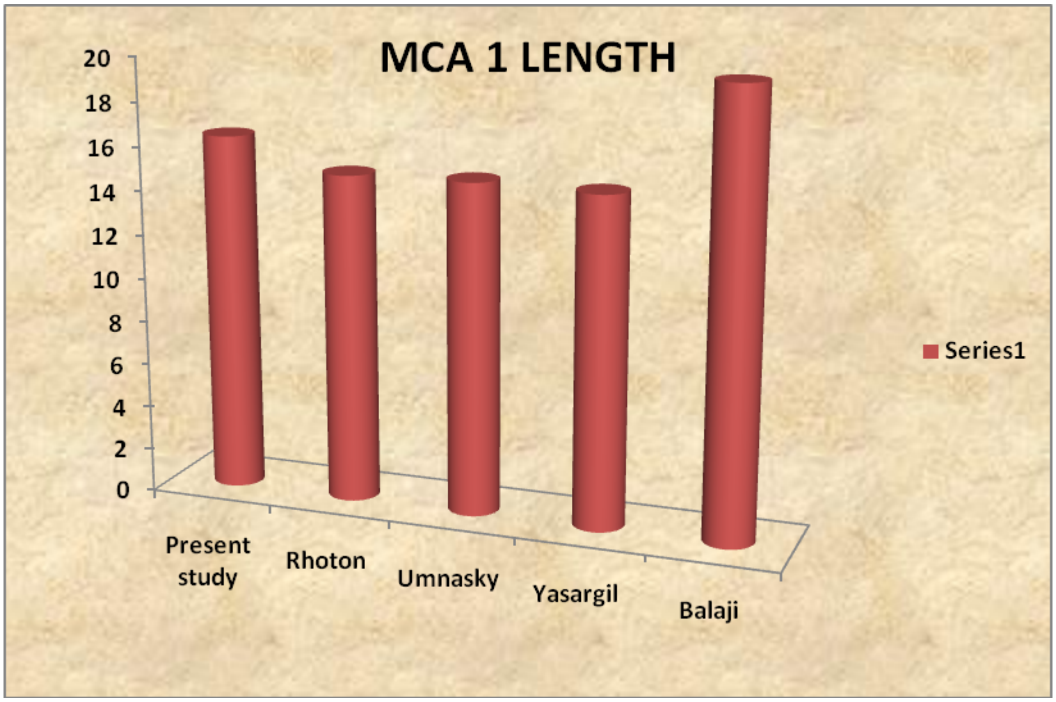
Largest of Cortical Arteries

	Frequency	**Percent**
LCA	16	53.4
LCTO	14	46.6

Either of angular artery or temporo occipital artery was the largest cortical artery in this sample and there were instances where both compensated when either of these arteries were absent.

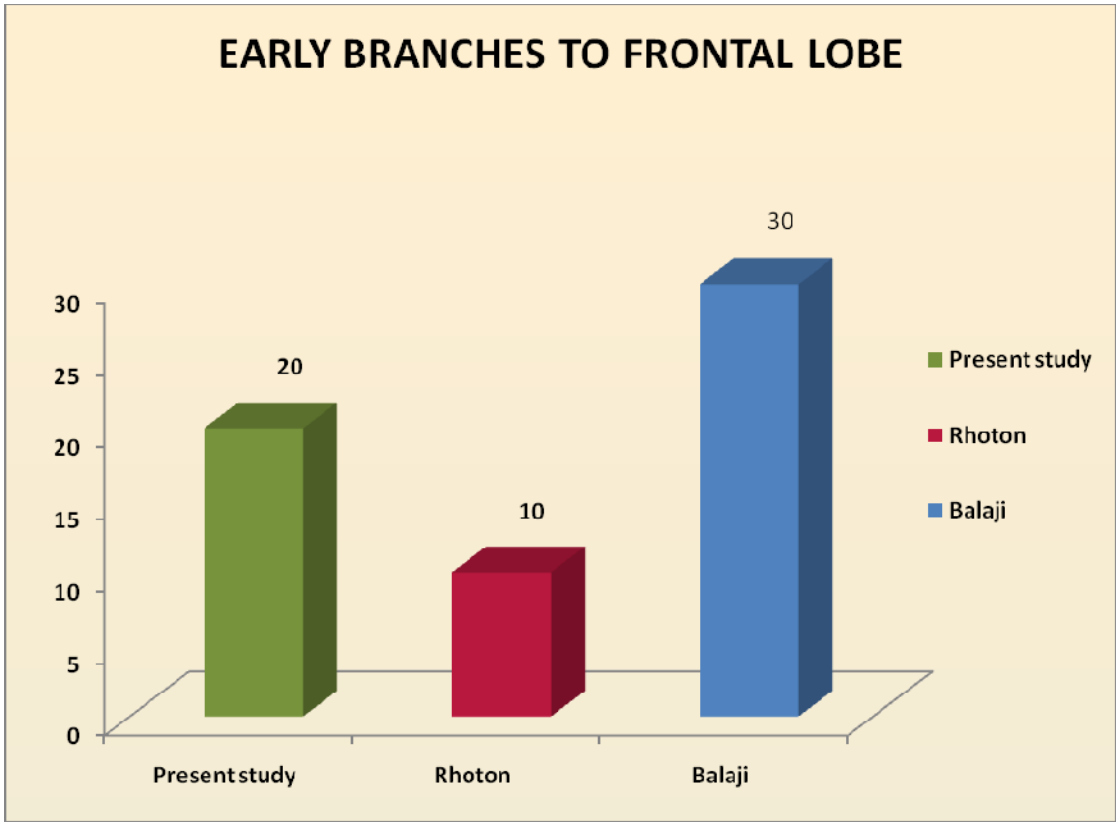
The angular artery was the largest cortical artery in 53.4% of cases.

The temporo occipital artery was the largest cortical artery in 46.6% of cases.



Present study	-	16.37
Rhoton	-	15
Umnasky	-	15.1
Yasargil	-	15
Balaji	-	20

When compared with the western studies the MCA1 length was longer by a few mm but it was longer in another Indian study.

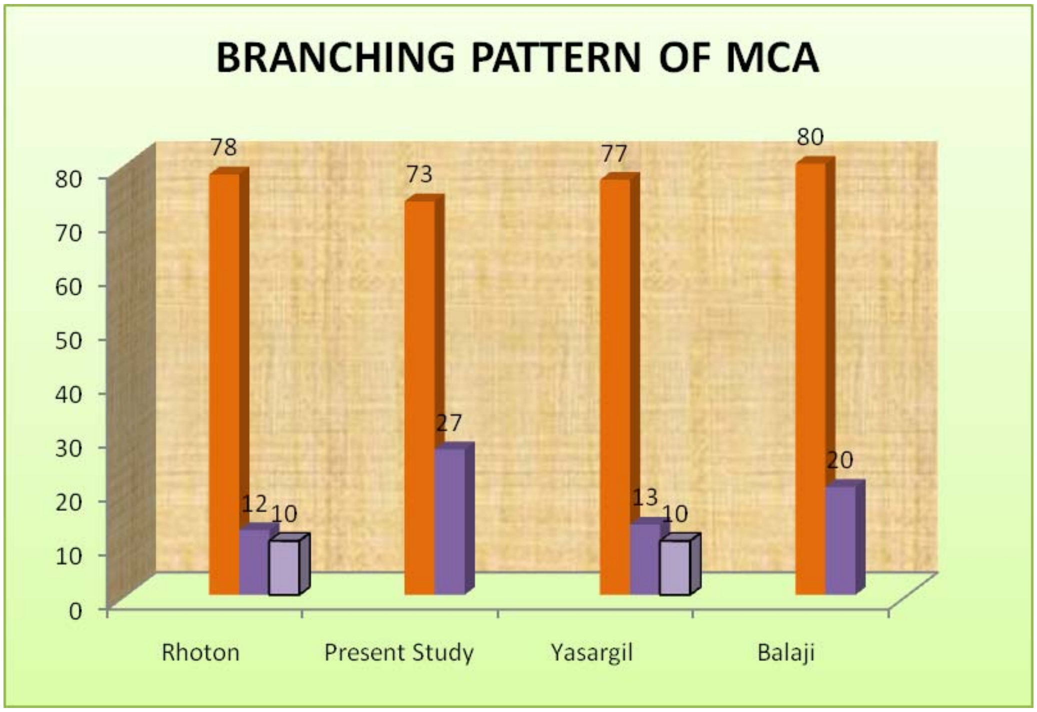


3. Early branches to frontal lobe

The early branch to the frontal lobe was 20% which is higher than the incidence reported by Rhoton (10%) and lower than the incidence published by Balaj Pai who has reported an (30%) incidence.

4. Accessory middle cerebral artery

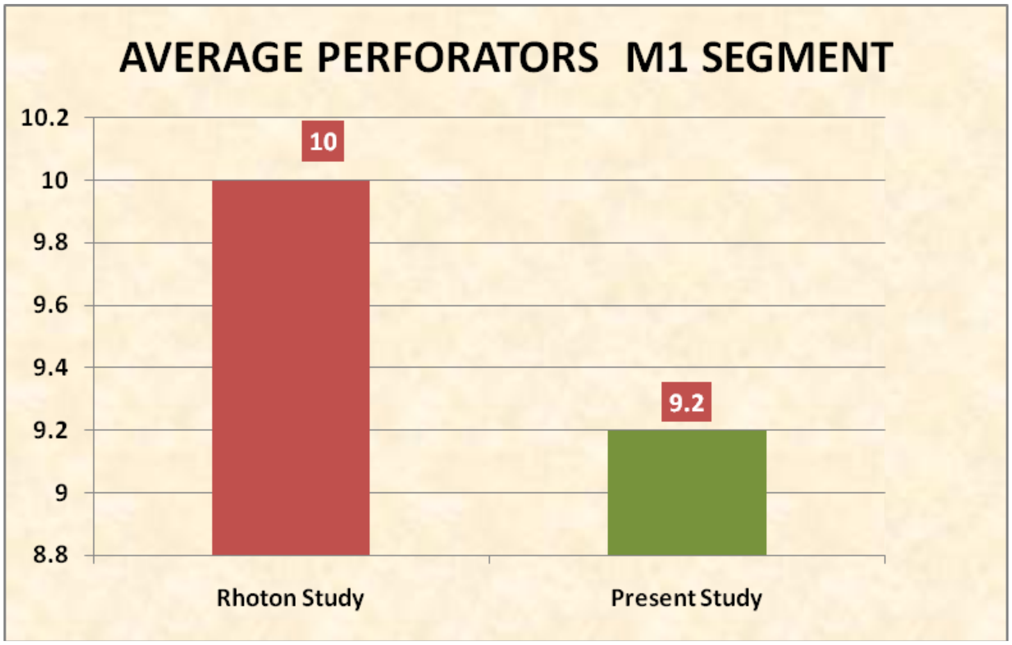
There was no cases which had an accessory MCA whereas Yasargil has recorded an incidence of 2.9%.



5. Branching pattern of MCA

Rhoton	-	78% (Bifurcated)
	-	12% (Trifurcated)
	-	10% (Multiple)
Present Study	-	73% (Bifurcated)
	-	27% (Trifurcated)
Yasargil	-	77% (Bifurcated)
	-	13% (Trifurcated)
	-	10% (Multiple)
Balaji	-	80% (Bifurcated)
	-	20% (Trifurcated)

Perforators M1 segment



The average number of M1segment perforators in this study was compared with the other study by Rhoton.

The average number of perforator in study by Rhoton study – 10

The average number of perforator in this study – 9.2

DISCUSSION

The different variables with regard to the middle cerebral artery in our in population was analyzed and compared with the studies in western population as well as with other Indian study with respect to the Anatomical perspectives and surgical considerations.

1) Middle cerebral artery is the largest branch of the internal carotid artery and it is in direct continuation with the internal carotid artery whereas the anterior cerebral artery forms an angle with that of ICA

2) The mean length of the MCA in this study was 16.37mm. It was also found to be shorter in length in cases with bifurcating MCA and longer in length in cases with trifurcating MCAs. This was also found to be shorter in length in cases with bifurcating MCA. This has been compared with the western studies which showed a slightly shorter MCA compared with this study sample.

3) Early branches were noted in all cases in this study and they were either single, two and more than two branches and in the last category which constituted 20% in this study one of the branches supplied the frontal lobe.

This was compared with few, studies where Rhoton reported 10% incidence of frontal lobe supply and Balajipai et al reported 30% incidence.

4) The incidence of accessory MCA though reported in different studies it was not found in this study sample

5) The perforators from the middle cerebral artery were found to arise predominantly from the inferomedial aspect with uniform distribution throughout the length of M1 segment. They entered the anterior perforated substance as described by the other studies. The average number of perforators distributed both in the proximal and distal segment was similar to other studies done in the western population.

6) The Branching pattern of middle cerebral artery showed bifurcation in 73% and trifurcation in 27%. In the majority of the cases there was symmetry in the division of the MCA between the two sides but a few cases showed difference between the two sides.

7) Similar to the way the MCA originates from ICA the dominant trunk of MCA is more in line with that of parent vessel and the non dominant trunk off shoots from the MCA at an angle.

8) The angular or temporooccipital artery was the largest of the cortical arteries observed.

- Embolic Stroke, (the commonest cause of stoke) and secondary deposits tend to affects the MCA territory as it is more parallel and in line with the MCA and comparatively larger in caliber and cross section.

- Involvement of the individual cortical branch may produce symptoms pertaining to the area supplied by that branch due to the variations in size and area of the cortex supplied it is difficult to identify the exact branch it is difficult to identify the block in these vessels even with angiography.

Surgical Consideration:

- The middle cerebral artery is mostly uniform in size but the gross variation in size of its counterpart the ACA pose a difficulty in locating the division preoperatively. A detailed angiographic evaluation prior to surgery is mandatory.

- Irrespective of the adequate length of MCA it is not freely mobile and its mobility is being restricted by the perforators.

- During aneurysm surgery the early branches from the superolateral aspect should be preserved as they supply the cortical areas replacing the cortical branches.

- Even though few perforators can arise from the accessory MCA they do not predominate in supply to any cortical area hence they can dispensed during surgery safely of at all needed.

5. During surgery in and around MCA the dissection is kept to a bare minimum in the inferomedial aspect since the likelihood of injury to the perforators is more in the event of doing so.

6. In aneurysm surgery of MCA the application of temporary clips should be as distal as possible in order to minimize the injury to the perforators as for as possible.

7. The perforators in the insula are dealt with care to avoid injury since it may cause limb weakness due to corono radiata and internal capsule involvement as a result of perforator injury. Hence extreme care should be taken to prevent the mobilization of these vessels.

8. In case of MCA occlusion the most preferred vessel for STMC bypass is angular artery or temporo occipital artery.

CONCLUSION

Middle cerebral artery is larger of the two branches of ICA and it is direct continuation with the ICA which favours any emboli to get lodged there resulting in stroke of that territory or secondaries to get deposited or abscess formation in that territory.

The length of M1 segment in shorter in the bifurcating MCAs and longer in trifurcating MCAs.

The mobility of the M2 segment is hampered by the interomedial perforators of the M1 segment.

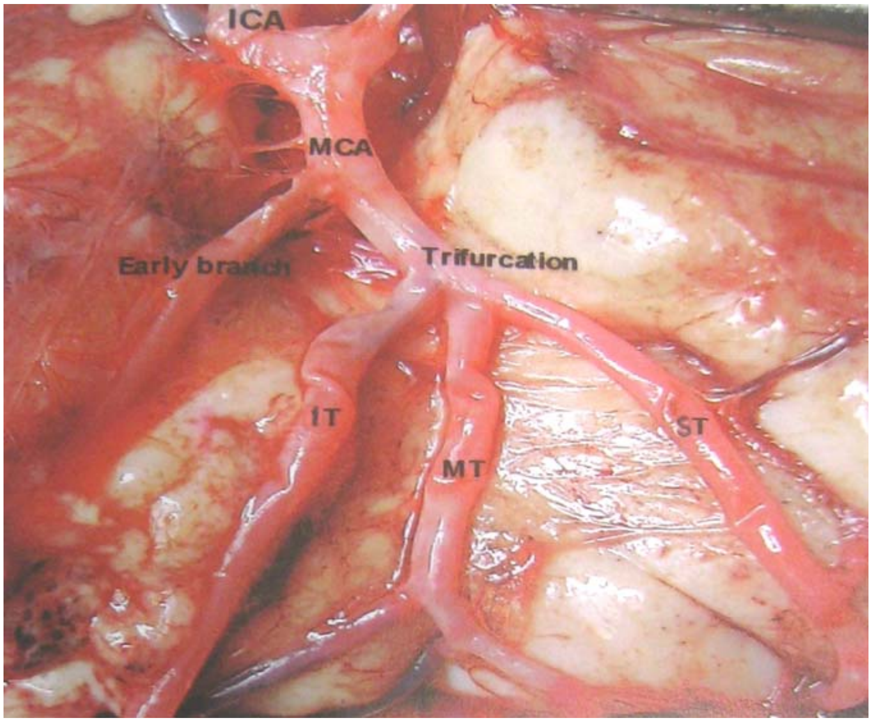
Accessory MCA or duplication of MCA is a rare phenomenon and they do not have specific cortical supply hence they can be sacrificed if necessary.

There is uniform distribution of perforators from the inferomedial aspect of MCA, hence dissection in that area should be minimal to avoid injury.

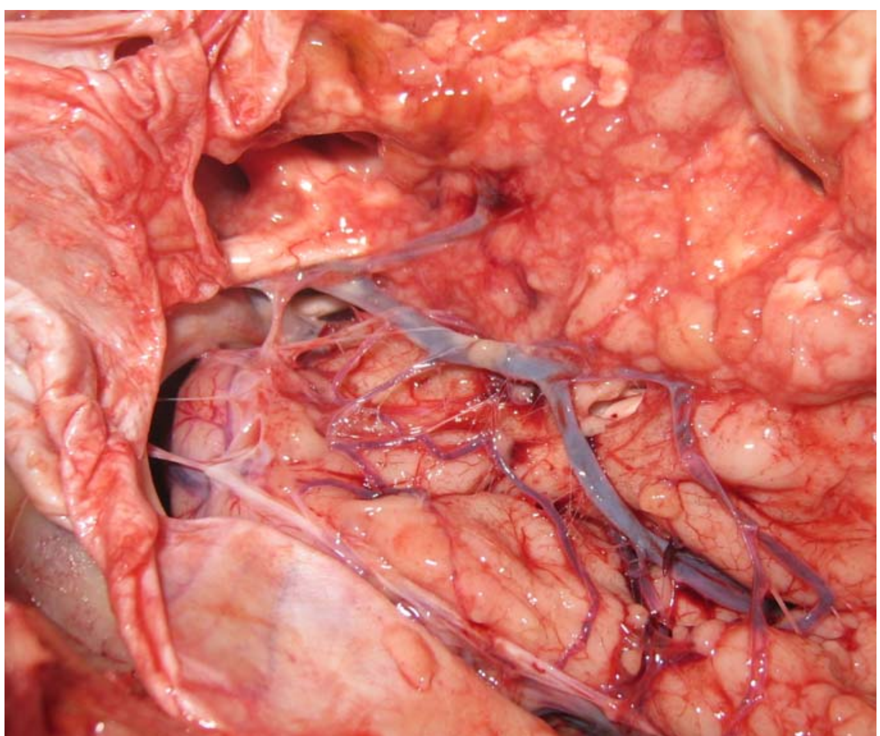
During anenrysm surgery the application of temporary clips should be as distal as possible to avoid injury to the perforators.

The branching pattern of the MCA should be elucidated with preoperative catheter angiogram or DSA since it is the common site of aneurysm.

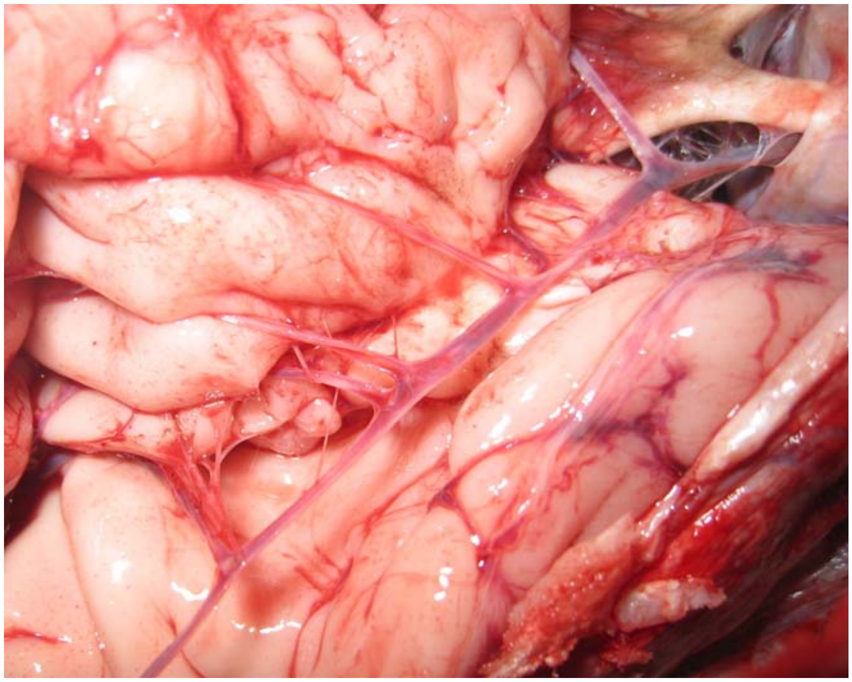
In case of ‘occlusion’ of middle cerebral artery contemplated for bypass the angular or temporo occipital area is the ideal and preferred vessels for anastomosis due to its shear size.



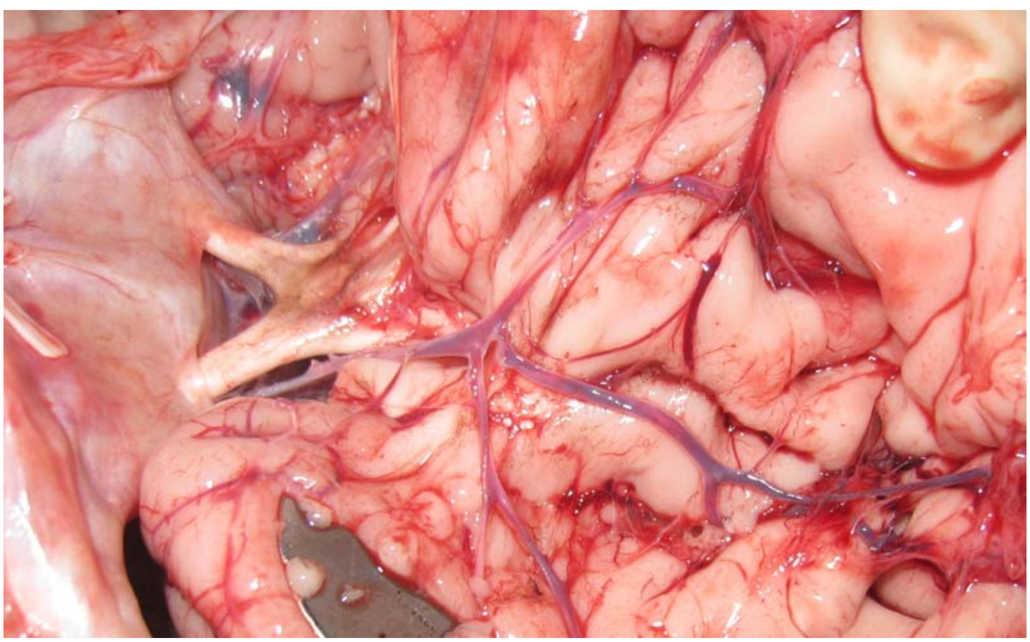
EARLY BRANCH FROM M1



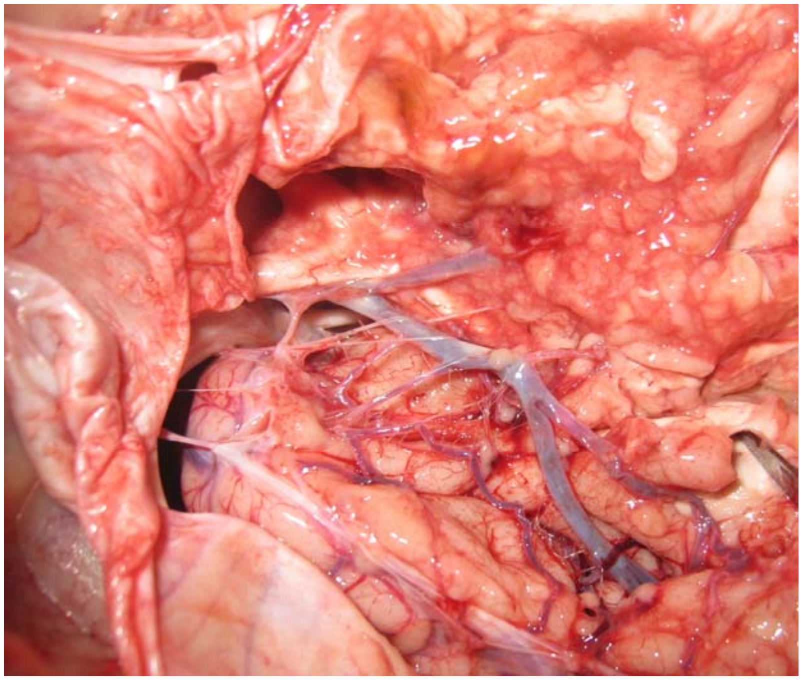
LENTICULOSTRIATE ARTERIES



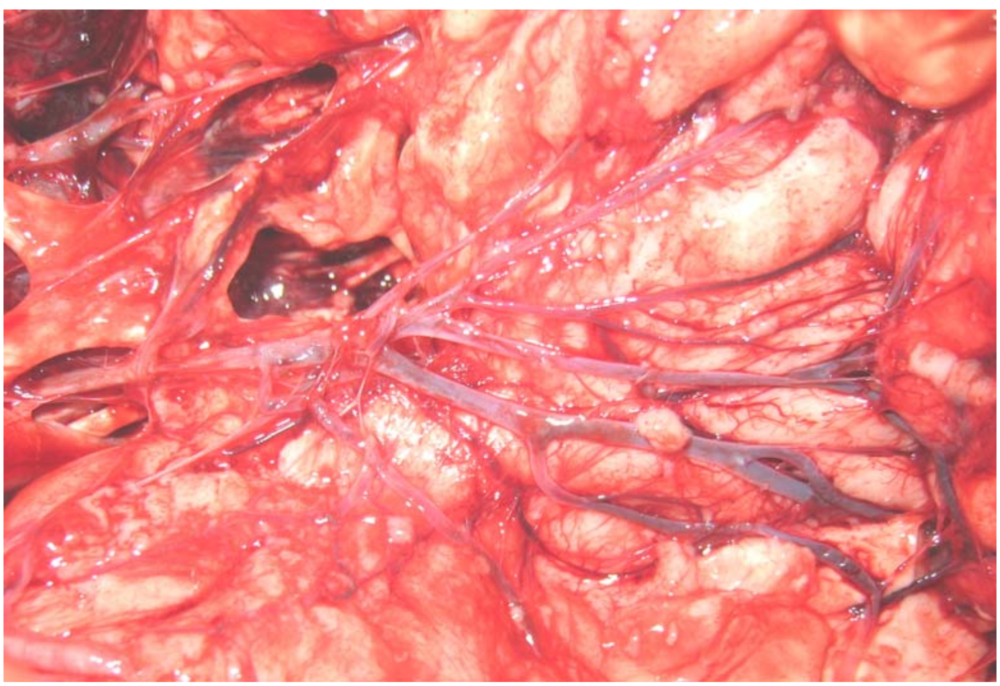
STEM ARTERIES



TRIFURCATION



PERFORATORS



MCA DIVISION

PROFORMA

Middle cerebral artery microsurgical anatomy

a) Side

b) Age/sex

Observations

1) MCA length – M1 segment

2) Early branches

3) Accessory MCA

4) Perforators :

   M1 segment

   Proximal

   Distal

   M2 segment perforators

5) M1 Branching

6) Largest cortical branch

MASTER CHART

Sl.No	Name	Age	Sex	Side	MCAL	ACCMCA	EBR	M1PP	M1DP	M2P	Bifurcation	Trifurcation	Multiple
1	Jeyakrishnan	28	M	R	18	0	3	10	2	1	1	0	0
2	Jeyakrishnan	28	M	L	16	0	3	7	6	0	1	0	0
3	Balammal	34	F	R	14	0	2	5	5	1	1	0	0
4	Balammal	34	F	L	14	0	2	6	4	2	1	0	0
5	Lalitha	19	F	R	12	0	1	7	3	0	1	0	0
6	Lalitha	19	F	L	13	0	1	5	3	0	1	0	0
7	Rajendran	34	M	R	16	0	1	9	4	2	1	0	0
8	Rajendran	34	M	L	16	0	1	13	4	1	1	0	0
9	Vignesh	24	M	R	18	0	2	6	2	1	1	0	0
10	Vignesh	24	M	L	16	0	1	7	2	3	1	0	0
11	Kalidass	28	M	R	18	0	2	9	5	2	1	0	0
12	Kalidass	28	M	L	18	0	2	8	2	1	1	0	0
13	Nagammal	56	F	R	32	0	3	8	3	0	0	1	0
14	Nagammal	56	F	L	21	0	3	9	2	1	0	1	0
15	Alagarsamy	67	M	R	24	0	2	6	2	4	0	1	0
16	Alagarsamy	67	M	L	21	0	2	5	3	2	0	1	0
17	Durairaj	43	M	R	18	0	3	7	3	1	1	0	0
18	Durairaj	43	M	L	16	0	2	8	2	3	1	0	0
19	Dhanasekaran	35	M	R	12	0	1	5	2	4	1	0	0
20	Dhanasekaran	35	M	L	14	0	1	9	2	1	1	0	0
21	Alagumani	23	F	R	13	0	1	6	3	3	1	0	0
22	Alagumani	23	F	L	14	0	1	7	1	0	0	1	0
23	Dharmar	44	M	R	18	0	2	6	0	1	0	1	0
24	Dharmar	44	M	L	16	0	2	4	3	0	0	1	0
25	Marimuthu	67	M	R	15	0	3	6	2	3	1	0	0
26	Marimuthu	67	M	L	18	0	2	7	3	0	0	1	0
27	Nallusamy	78	M	R	14	0	2	8	4	2	1	0	0
28	Nallusamy	78	M	L	13	0	2	5	3	2	1	0	0
29	Shanthi	46	F	R	16	0	1	6	2	3	1	0	0
30	Shanthi	46	F	L	17	0	2	8	2	2	1	0	0

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